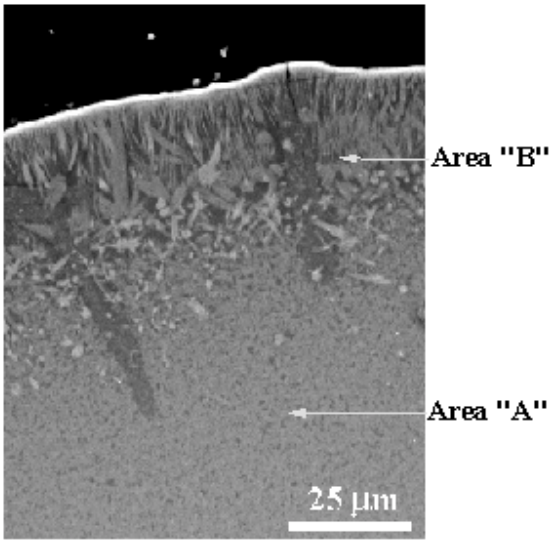
Corrosion Mechanisms of a Bioceramic

The chemical durability of dental ceramics is an important factor in their clinical performance. Under service conditions, dental ceramics are exposed to a wide variety of aqueous environments. The chemical durability of silicate dental ceramics depends on their composition and their microstructure (i.e., the arrangement of crystals). While dental materials must have good long-term corrosion behavior *in vivo*, a great deal of useful information can be gathered through *in vitro* laboratory corrosion studies.

The CMT Waste Materials Research Department is a leader in the study of aqueous corrosion of ceramics and glasses. Recently, we have applied this expertise to a dental ceramic with the goal of describing the processes involved in its corrosion. If these processes are understood, then the dental ceramic can be altered to minimize their impact. For example, the chemical durability of the ceramic might be improved by the replacement of Na and K with Ca to minimize ion exchange, or the addition of Al to minimize matrix dissolution. In addition, changes in the fabrication procedure might improve the microstructure of the dental ceramic.

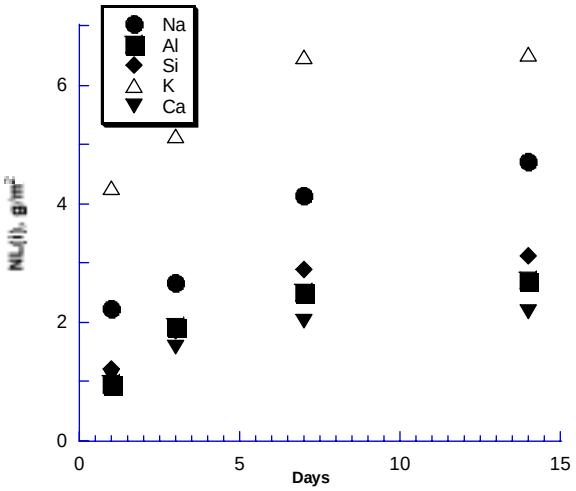
The corrosion tests in this study were conducted according to the MCC-1 procedure at 90°C for 1, 3, 5, 7, and 14 days. At the end of the test, the pH and cation concentrations of the leachate were measured.

Microscopic examination of a polished cross section of a fluorocanasite dental ceramic showed that the microstructure was heterogeneous with two phases present. The interior of the monolith contained tightly packed, fine-grained canasite with glass between the crystals (area A in micrograph). The microstructure near the edges was quite different and contained large regions of glass and crystals of varying orientations and sizes (area B in micrograph). The cooling history of the dental ceramic, which differs slightly for the edges of the monolith compared with the interior, is the most likely cause of the microstructure.



Scanning Electron Micrograph of an Unreacted Fluorocanasite Dental Ceramic

The losses of five elements from the dental ceramic were quantified as the normalized mass loss [NL(i), in g/m^2] (amount of ceramic dissolved, based on elemental release, divided by the sample surface area). As shown in the figure on the next page, the NL(i) values for each of the elements increased rapidly from 1 to 7 days. The corrosion rates based on these data were constant between 1 and 7 days and ranged from 0.15 to 0.36 $g/(m^2 \cdot day)$. These results suggest that the dental ceramic corroded at the maximum attainable rate at the given test conditions.

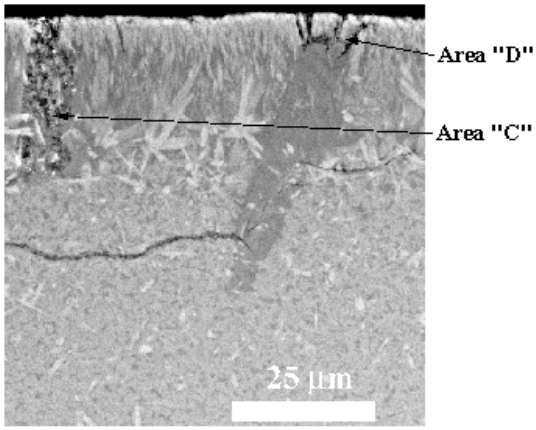


Normalized Mass Losses for Several Elements as a Function of Reaction Time for Fluorocanasite Dental Ceramic

The corrosion rates based on Si, Al, and Ca were similar and are lower than those based on Na and K. Because any calcium released was from dissolution of canasite, the corrosion rate based on calcium [0.15 g/(m^2·day)] represents the corrosion of canasite. On the other hand, the glass contains much more potassium than does the canasite, so the corrosion rate based on potassium [0.8 g/(m^2·day)] represents the corrosion of the glass. The release of Na^+ and K^+ as well as an increased pH resulted from an ion-exchange reaction between the cations in the glass for H^+ in the solution. Therefore, the corrosion of the glass was faster than the corrosion of the canasite crystals.

Microscopic examination of a reacted monolith of the dental ceramic gave further evidence of the preferential glass corrosion. The dark, pitted region (area C in micrograph) is reacted glass, and the "top" of another glass-rich region (area D in micrograph) results from glass corrosion.

The glass phase near the cast edges of the dental ceramic monoliths was most affected by the corrosion. An ion exchange of H^+ from the solution with K^+ and Na^+ from the glass increased the pH and the concentrations of K^+ and Na^+. The rate of the ion exchange reaction in the glass is high, about 0.8 g/(m^2·day). The rate of canasite dissolution is quite low, about 0.15 g/(m^2·day). An improvement in the corrosion behavior of this dental ceramic might result from changes in the fabrication procedure that would reduce the amount of glass regions near the edges of the monolith.



Scanning Electron Micrograph of a Reacted Fluorocanasite Dental Ceramic

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